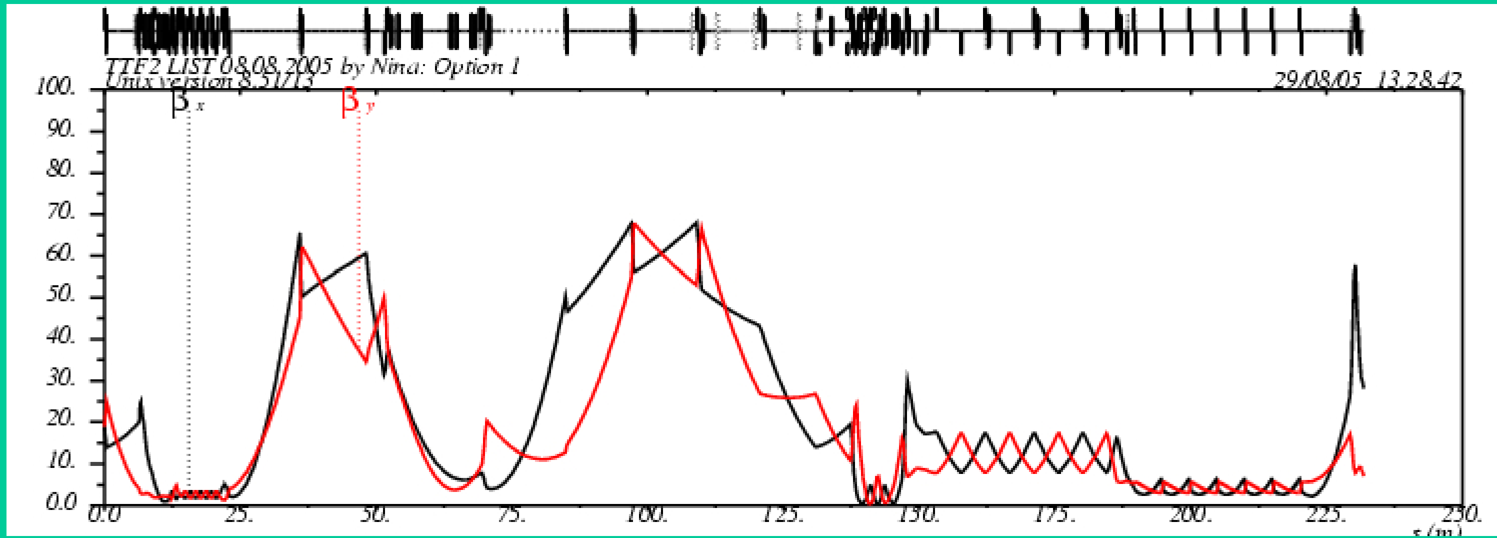
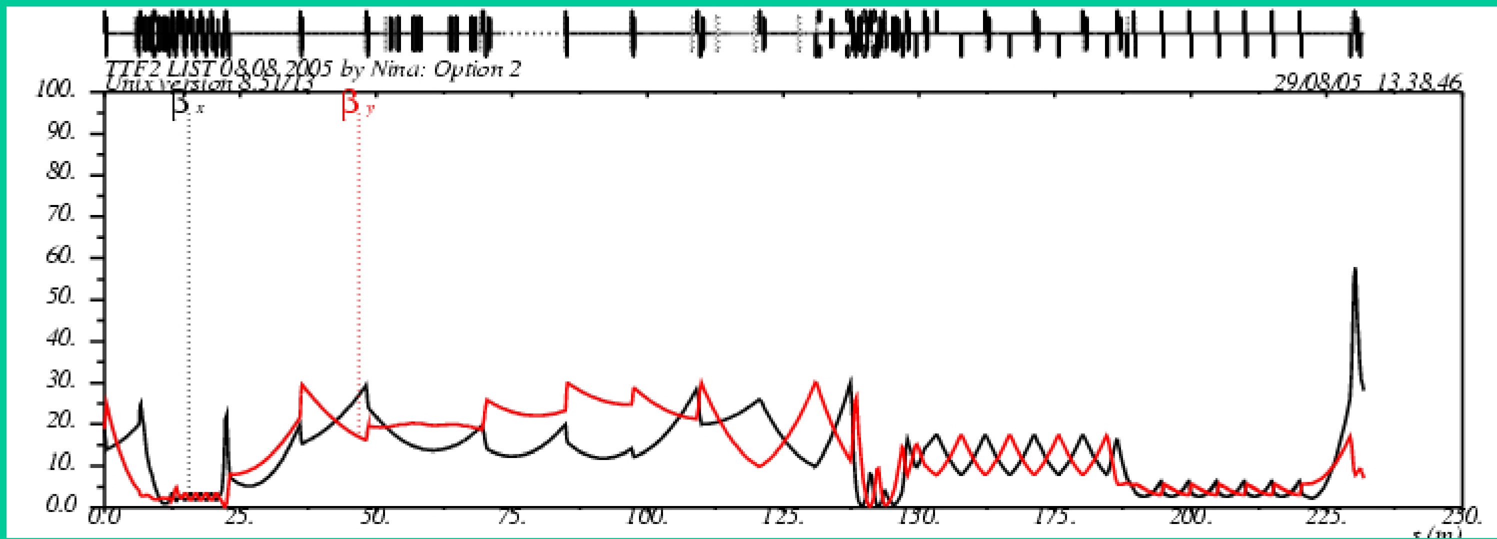
Sensitivity to quadrupole errors in two options for TTF optics

V. Balandin, N.Golubeva, 12 September 2005

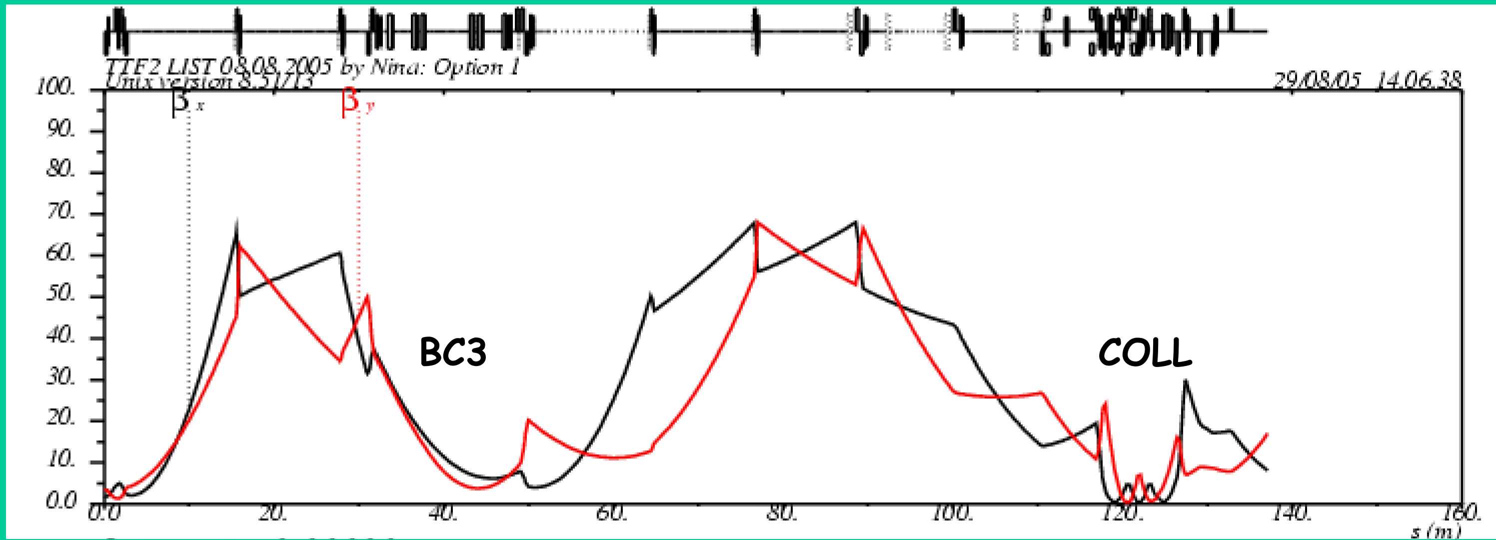
Two options for TTF optics



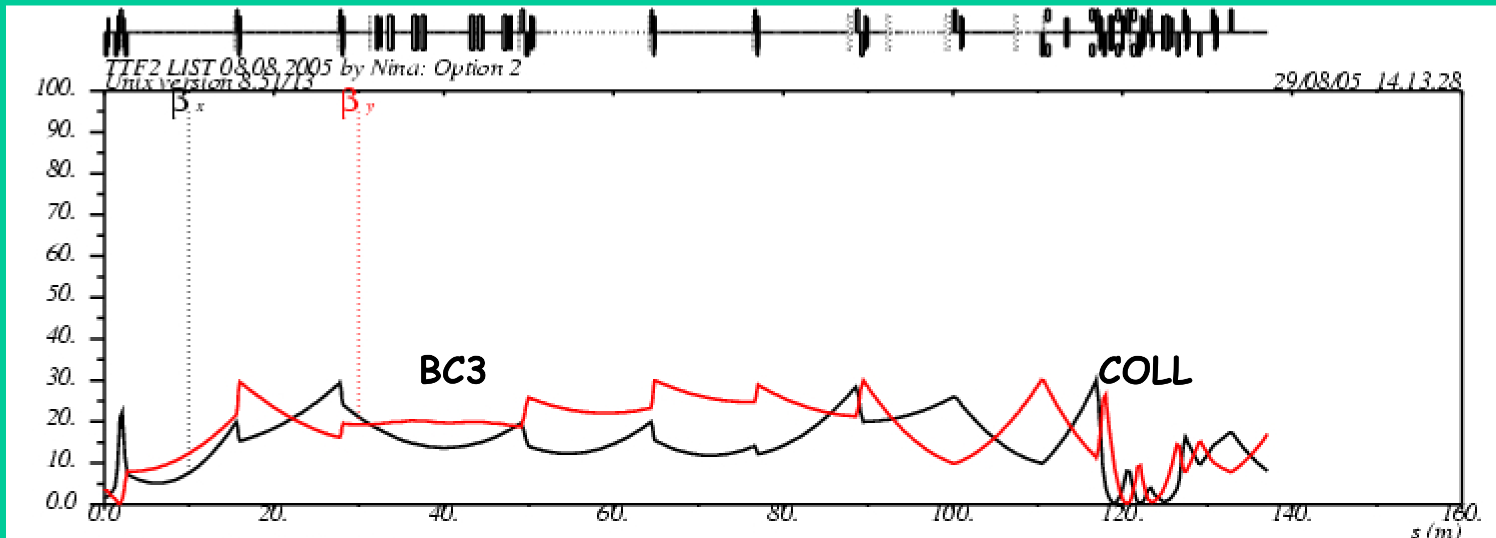


August 2005: Undulator V4: ABS = 3.6 m
Accelerating gradients: close to operation

Two options for TTF optics: tunable sections



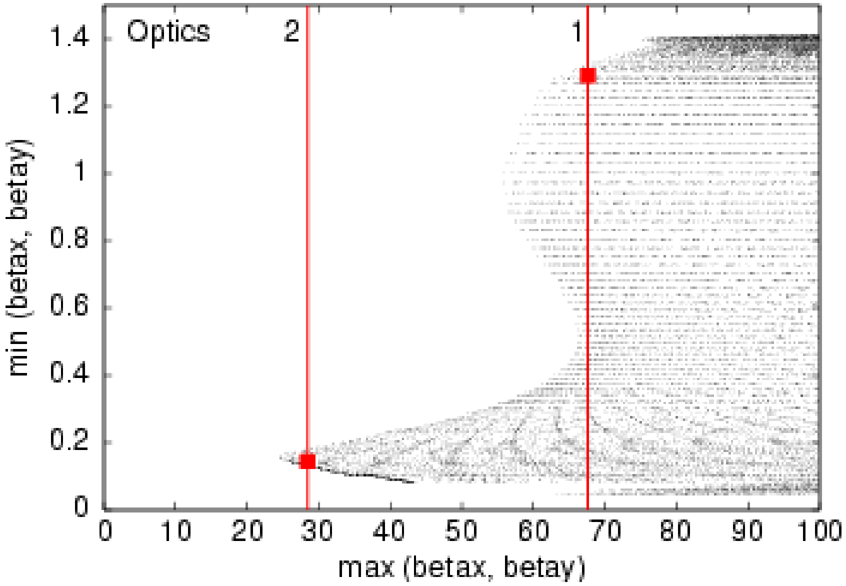
$\beta\_min \approx 0.35$ m in COLLIMATOR



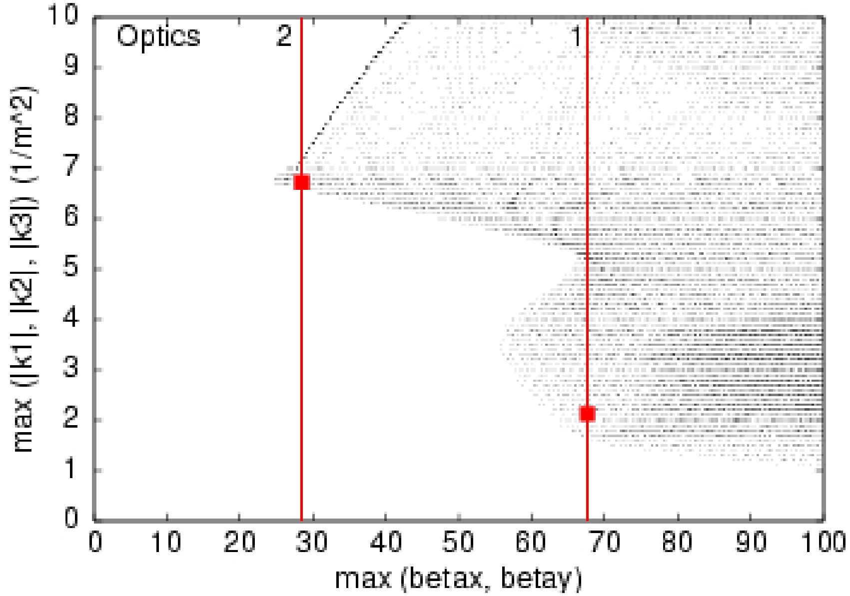
$\beta\_min \approx 0.15$ m in DBC2

Q1/2UBC3
Q1DBC3
are not used

Why two options for TTF optics ?



The transition from DBC2 diagnostic section into accelerating module ACC2: Scan over possible strengths of 3 quads downstream of DBC2 FODO => max and min values of β-functions are calculated in the section containing these 3 quads and 8 cavities of ACC2 (no RF focusing).



At the reducing of **max (βx, βy)** there are sudden jumps both in maximum of **min (βx, βy)** and in minimum of **max(|k_i|);** and there is no continuous transition between two optics.

Definition of sensitivity used for optics comparison

Let $\vec{\Delta} = (\Delta_1, \ldots, \Delta_n)$ be a vector of quadrupole errors and $\tilde{\beta}$ be a resulting (perturbed) β-function. Then

$$\frac{\tilde{\beta}}{\beta} = \frac{1}{2}\left(\lambda + \frac{1}{\lambda}\right) + \frac{1}{2}\left(\lambda - \frac{1}{\lambda}\right)\cos(2\mu - 2\theta)$$

$$\lambda = M_p + \sqrt{M_p^2 - 1}, \qquad M_p = \frac{\beta\tilde{\gamma} - 2\alpha\tilde{\alpha} + \tilde{\beta}\gamma}{2}$$

$$\frac{1}{\lambda} \leq \frac{\tilde{\beta}}{\beta} \leq \lambda$$

The lower order in $\vec{\Delta}$ gives

$$\left|\frac{\Delta\beta}{\beta}\right| = \left|\frac{\tilde{\beta} - \beta}{\beta}\right| \leq \sqrt{2\,M\,\vec{\Delta}\cdot\vec{\Delta}} + \text{high order terms}$$

where $M = (m_{ij})$ is a *sensitivity matrix*.

As a sensitivity to an error in a single quadrupole we will consider

$$\sqrt{2\,m_{ii}^{x}} \quad \text{and} \quad \sqrt{2\,m_{ii}^{y}}$$

Comparison of sensitivity for two optics

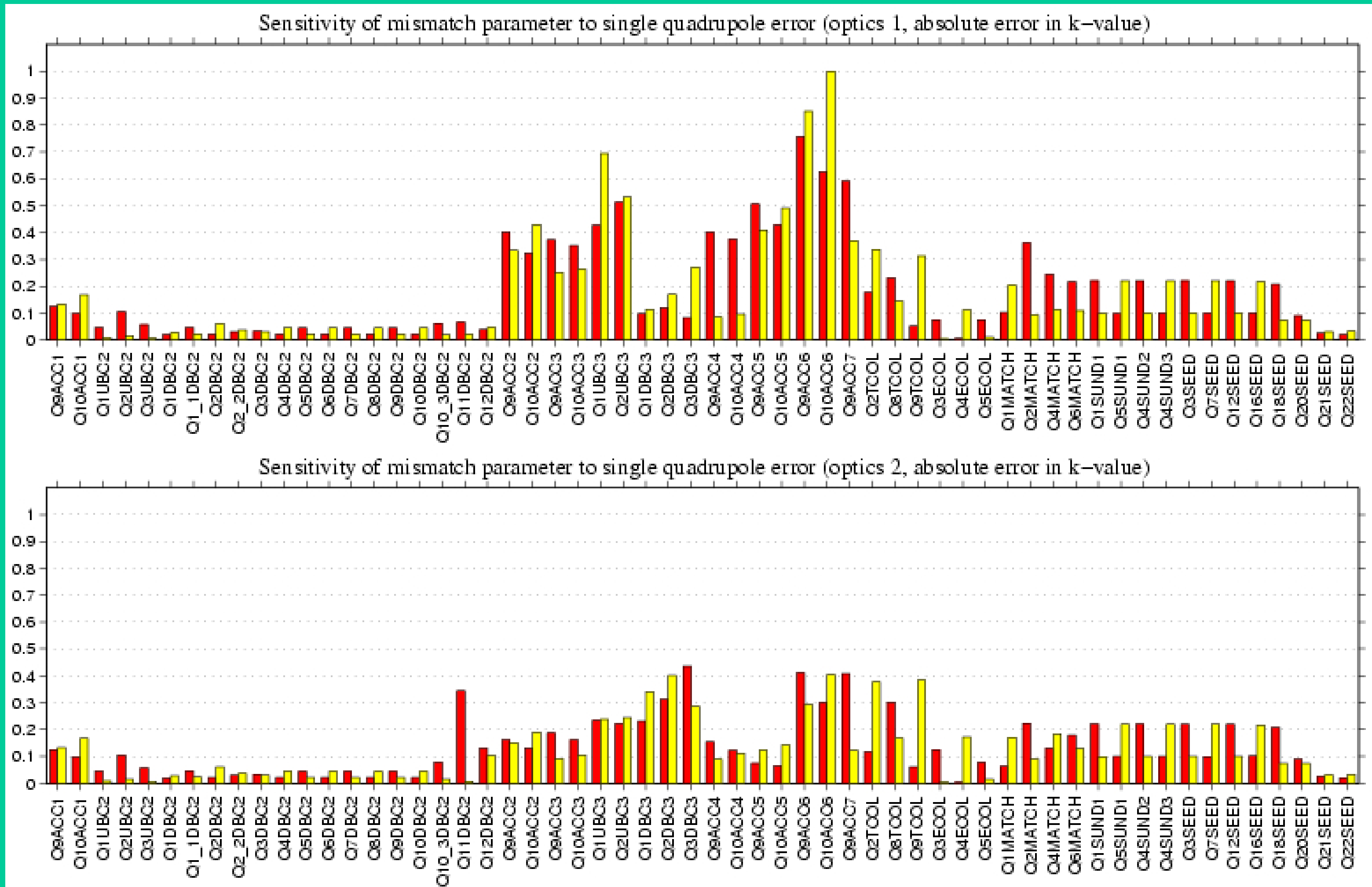
Another important value for optics comparison is

$$\mathbf{Tr_{x,y}} = \mathbf{Tr}(\mathbf{M_{x,y}}) = \sum_{i=1}^{n} \mathbf{m_{ii}^{x,y}}$$

$$\sqrt{\mathbf{Tr_x}} \quad \text{and} \quad \sqrt{\mathbf{Tr_y}}$$

Errors in k-values	absolute		relative	
	x	y	x	y
Option 1 :	8.76	9.28	16.25	16.34
Option 2 :	5.91	5.77	15.43	11.38

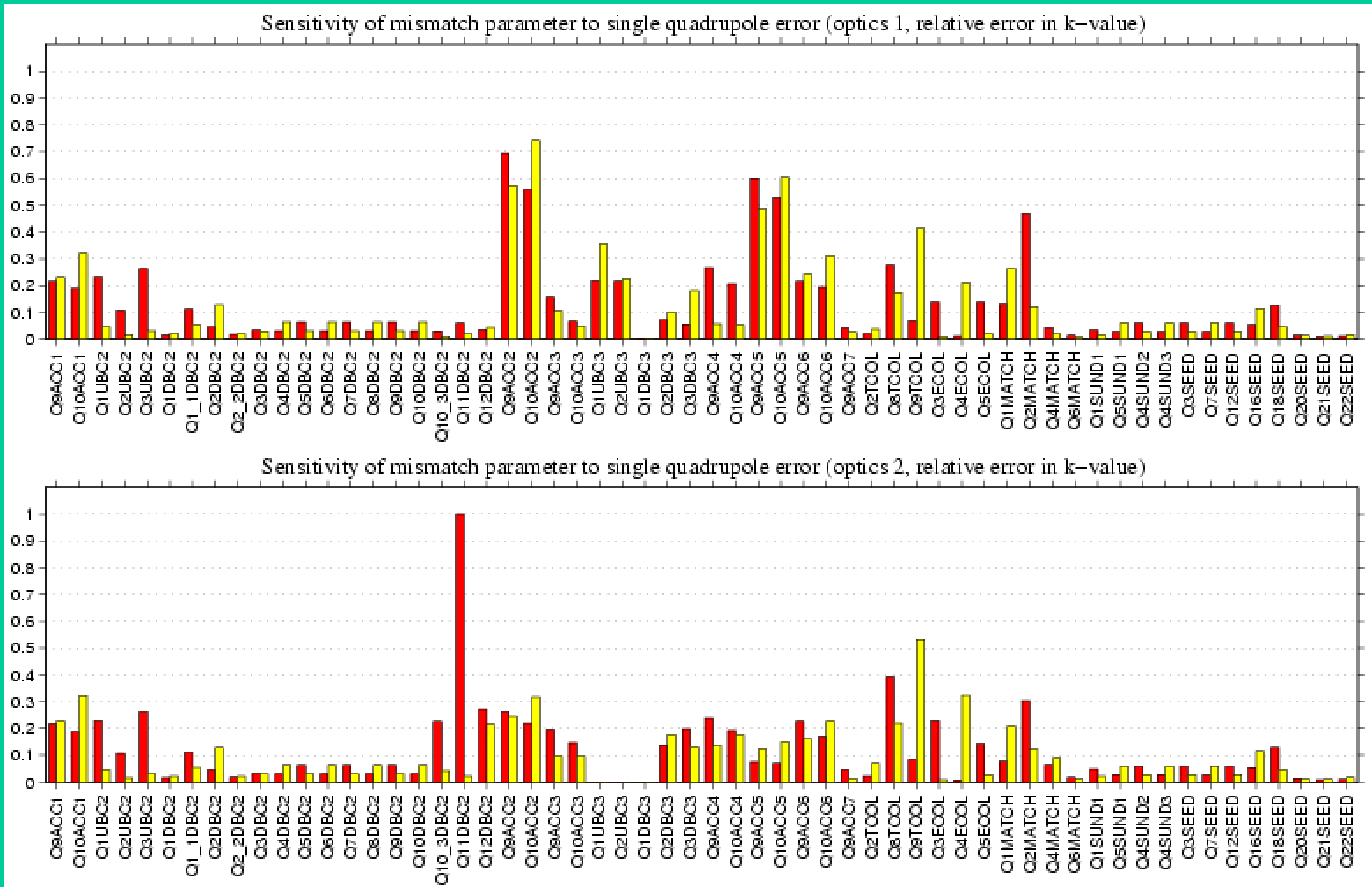
Sensitivity to single quadrupole error: absolute error in k-values



horizontal

vertical

Sensitivity to single quadrupole error: relative error in k-values



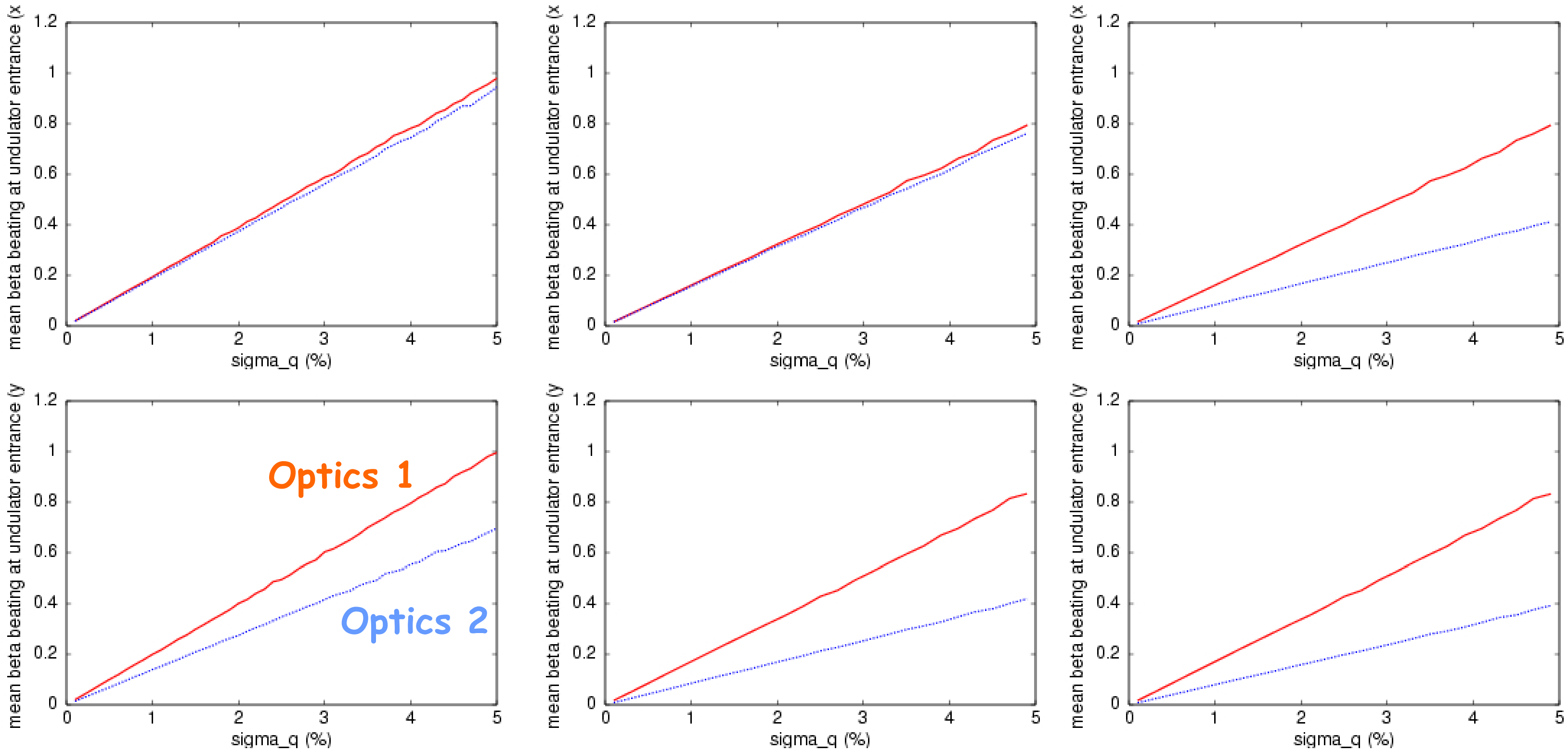
horizontal vertical

Beta beating at undulator entrance

- Relative error in quadrupole strengths
- Error distribution: quadrupole errors are uncorrelated, and have a Gaussian distribution

Hor plane

Ver plane



Errors: all quads | Q10.3DBC2-Q9ACC7 | Q9ACC2-Q9ACC7